

# Evaluation of the effects of dietary fat, conjugated linoleic acid, and ractopamine on growth performance, pork quality, and fatty acid profiles in genetically lean gilts<sup>1</sup>

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**ABSTRACT:** An 8-wk study of the effects of CLA, rendered animal fats, and ractopamine, and their interactive effects on growth, fatty acid composition, and carcass quality of genetically lean pigs was conducted. Gilts (n = 228; initial BW of 59.1 kg) were assigned to a 2 × 2 × 3 factorial arrangement consisting of CLA, ractopamine, and fat treatments. The CLA treatment consisted of 1% CLA oil (CLA-60) or 1% soybean oil. Ractopamine levels were either 0 or 10 ppm. Fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT). The CLA and fat treatments were initiated at 59.1 kg of BW, 4 wk before the ractopamine treatments. The ractopamine treatments were imposed when the gilts reached a BW of 85.7 kg and lasted for the duration of the final 4 wk until carcass data were collected. Lipids from the belly, outer and inner layers of backfat, and LM were extracted and analyzed for fatty acid composition from 6 pigs per treatment at wk 4 and 8. Feeding CLA increased ( $P < 0.02$ ) G:F during the final 4 wk. Pigs fed added fat as either CWG or BT exhibited decreased ( $P < 0.05$ ) ADFI

and increased ( $P < 0.01$ ) G:F. Adding ractopamine to the diet increased ( $P < 0.01$ ) ADG, G:F, and final BW. The predicted carcass lean percentage was increased ( $P < 0.05$ ) in pigs fed CLA or ractopamine. Feeding either 5% fat or ractopamine increased ( $P < 0.05$ ) carcass weight. Adding fat to the diets increased ( $P < 0.05$ ) the 10th rib backfat depth but did not affect predicted percent lean. Bellies of gilts fed CLA were subjectively and objectively firmer ( $P < 0.01$ ). Dietary CLA increased ( $P < 0.01$ ) the concentration of saturated fatty acids and decreased ( $P < 0.01$ ) the concentration of unsaturated fatty acids of the belly fat, both layers of backfat, and LM. Ractopamine decreased ( $P < 0.01$ ) the i.m. fat content of the LM but had relatively little effect on the fatty acid profiles of the tissues compared with CLA. These results indicate that CLA, added fat, and ractopamine work mainly in an additive fashion to enhance pig growth and carcass quality. Furthermore, these results indicate that CLA results in more saturated fat throughout the carcass.

**Key words:** conjugated linoleic acid, dietary fat, fatty acid, pig growth, ractopamine

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## INTRODUCTION

The pork industry is constantly seeking economical methods that will increase production efficiency and carcass quality. Adding animal fats to swine diets enhanced G:F (Seerley et al., 1978; Stahly and Cromwell,

1979). It is also well known that the fatty acid composition of the pig reflects the fatty acid pattern of the diet (Ellis and Isbell, 1926; Warnants et al., 1999).

The use of the beta adrenergic agonist ractopamine increased growth rate, G:F, and carcass leanness (Stoller et al., 2003; Williams et al., 1994). Feeding ractopamine decreased fatty acid synthesis in porcine adipose tissue (Mills et al., 1990; Mersmann, 1998), which could alter the fatty acid composition of the adipose tissue. Furthermore, fatty acid synthase mRNA and ultimately fatty acid synthesis decreased in pigs treated with porcine somatotropin (Mildner and Clarke, 1991). Indeed, porcine somatotropin treatment altered the composition of fatty acids in adipose tissue and LM by increasing the abundance of unsaturated fatty acids (UFA; Ramsay et al., 2001). However,

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changes in the fatty acid composition of carcass tissues from pigs fed ractopamine have not been reported.

Adding CLA to swine diets reduced carcass fat (Dugan et al., 1997) and increased belly firmness (Eggert et al., 2001). Feeding CLA increased the abundance of SFA in porcine muscle (Joo et al., 2002), adipose tissue (Bee, 2000; Eggert et al., 2001), and bellies (Eggert et al., 2001). The current study was designed to determine whether ractopamine and rendered animal fats alter the fatty acid content of porcine carcasses and also to determine whether CLA can counteract the effects of ractopamine and dietary fat on the lipid content of carcass tissues.

## MATERIALS AND METHODS

### *Animals, Experimental Design, and Housing*

A total of 228 genetically lean female pigs (Newsham XL sires  $\times$  Duroc  $\times$  Yorkshire Landrace dams; initially, 59.10 kg, SD = 3.0 kg) were randomly assigned (blocked by BW) to a  $2 \times 3$  factorial arrangement consisting of dietary CLA and added fat treatments. The CLA treatment consisted of 1% of a commercially available CLA product containing 60% CLA isomers (0.6% CLA) or 1% soybean oil. Dietary fat treatments consisted of 1) diets containing 0% added fat, 2) diets containing 5% choice white grease (CWG), or 3) diets containing 5% beef tallow (BT). After a period of 4 wk (phase 1), when the average BW reached 85.67 kg (SD = 5.0 kg), the pigs were further allocated to receive diets containing 10 ppm of the complete diet containing ractopamine hydrochloride or diets containing no ractopamine hydrochloride in a  $2 \times 2 \times 3$  factorial arrangement consisting of ractopamine level (0 or 10 ppm of complete diet), dietary CLA level, and added fat level (phase 2).

The pigs were housed in an all-in/all-out curtain-sided grower-finisher facility and reared in groups of 3 pigs per pen (1.8 m<sup>2</sup>/pig) except for one block that contained 7 pigs per pen (0.8 m<sup>2</sup>/pig) during the first phase (wk 0 to 4) of the experiment. At the completion of phase 1 (wk 0 to 4), a subset of the pigs (n = 48; 4 pigs per pen from a block containing extra pigs; 8 pigs per dietary treatment) was removed from the trial to obtain carcass and belly quality data and fatty acid profiles. Therefore, there were 10 replicate pens per dietary treatment for the first 4 wk of the trial and 5 replicate pens per treatment for the remainder of the growth trial (phase 2). All pigs had ad libitum access to feed and water through a one-hole self-feeder and a nipple waterer. The animal handling protocols were approved by the Purdue University Animal Care and Use Committee.

### *Experimental Diets and Growth Performance*

All diets were formulated to meet or exceed the estimated nutrient requirements (NRC, 1998). The pigs

were fed 2 dietary phases with phase changes occurring after 4 wk. Dietary treatments within each phase were formulated to contain equivalent lysine/MCal of ME (Table 1). Diets containing CLA were formulated to provide 0.6% added CLA (1% of a product containing 60% CLA isomers (30.1% *cis*-9, *trans*-11; 31.4% *trans*-10, *cis*-12; and 0.02% *trans*-9, *cis*-11; Natural Lipids, Hovdebygda, Norway); the CLA oil was added at the expense of soybean oil. The fatty acid profiles of the supplemental fats and oils are presented in Table 2. For phase 2 diets containing ractopamine hydrochloride (Paylean; Elanco Animal Health, Indianapolis, IN), the ractopamine hydrochloride premix was added at the expense of corn. The pigs and feeders were weighed every 14 d to determine ADG, ADFI, and G:F.

### *Carcass Characteristics*

When the average BW reached 112.5 kg (SD = 5.4 kg, n = 180) the pigs were transported to the Purdue University Abattoir where carcass data were collected. Hot carcass weight was determined at the time of slaughter. The pH of the LM was measured at the 10th rib 45 min and 24 h postmortem using a Beckman  $\Phi$  110 ISFET pH meter with a spear-tipped KCl probe (Beckman Inc., Fullerton, CA). At 24 h postmortem the following measurements were taken on the ribbed carcasses: midline backfat depth at the last rib, inner layer backfat depth at the 10th rib, outer layer backfat depth at the 10th rib, and loin eye area. Percentage lean content of the carcasses was calculated using the equation for ribbed carcasses (NPPC, 1991).

### *Longissimus Muscle Quality Measurements*

At 24 h postmortem, after a 15 min bloom, subjective measurements of LM color, marbling, and firmness were taken on the carcasses at the interface of 10th and 11th rib (NPPC, 1999). Water holding capacity was analyzed using the drip loss method (Rasmussen and Stouffer, 1996). Briefly, muscle samples were collected from one of the 2.5-cm chops using a 2.5-cm coring device. The samples (triplicate 7-g core samples/chop) were then placed into the drip loss tubes so that the cut surface of the chop was perpendicular to the long axis of the drip loss tube. After 24 h at 4°C, the drip loss containers plus sample was reweighed. The muscle sample was then removed, and the container containing the exudates was reweighed. Therefore, the drip loss was calculated as the percentage of the mass of the original chop sample that the exudates represented.

### *Belly Firmness Measurements*

At 24 h postmortem the portion of the belly anterior to the 10th rib was removed from the carcass and placed skin side down and centered horizontally over

**Table 1.** Composition of experimental diets, as-fed basis

Item, %	Phase 1 (59 to 86 kg)		Phase 2 (86 to 112 kg)	
	Control	Added fat	Control	Added fat
Corn	75.80	68.22	68.76	60.03
Soybean meal (46.5% CP)	20.01	22.66	27.25	31.04
Dicalcium phosphate	1.35	1.37	1.19	1.18
Added fat <sup>1</sup>	—	5.00	—	5.00
Soybean oil <sup>2</sup>	1.00	1.00	1.00	1.00
Limestone	0.91	0.88	0.94	0.92
Salt	0.30	0.30	0.25	0.25
Vitamin premix <sup>3</sup>	0.15	0.15	0.15	0.15
Trace mineral premix <sup>4,5</sup>	0.10	0.10	0.09	0.09
Lysine·HCl	0.13	0.13	0.13	0.10
Ethoxyquin	0.05	0.05	0.05	0.05
Micro-aid	0.10	0.10	0.10	0.10
Selenium premix <sup>6</sup>	0.05	0.05	0.05	0.05
Antibiotic <sup>7</sup>	0.05	0.05	—	—
Ractopamine·HCl <sup>8</sup>	—	—	0.05	0.05
Calculated analysis				
CP, %	15.80	16.42	18.64	19.72
Lysine, %	0.90	0.96	1.10	1.17
ME, Mcal/kg	3.34	3.57	3.35	3.58
Lysine, g/Mcal	2.69	2.68	3.28	3.26
Ca, %	0.70	0.70	0.70	0.70
P, %	0.60	0.60	0.60	0.60

<sup>1</sup>The added fat diets contained 5% choice white grease or 5% beef tallow.

<sup>2</sup>In diets containing CLA 1% of a product consisting of 60% CLA isomers replaced soybean oil.

<sup>3</sup>Provided per kg of complete diet: vitamin A, 3,630 IU; vitamin D<sub>3</sub>, 363 IU; vitamin E, 26.40 IU; menadione, 1.20 mg; vitamin B<sub>12</sub>, 0.02 mg; riboflavin, 4.22 mg; pantothenic acid, 13.20 mg; and niacin, 19.80 mg.

<sup>4</sup>Provided per kg of complete diet in phase 1: Fe, 96.78 mg; Zn, 96.78 mg; Mn, 11.98 mg; Cu, 8.98 mg; and I, 0.33 mg.

<sup>5</sup>Provided per kg of complete diet in phase 2: Fe, 84.68 mg; Zn, 84.68 mg; Mn, 10.48 mg; Cu, 7.86 mg; and I, 0.29 mg.

<sup>6</sup>Provided 0.30 mg of Se per kilogram of complete diet.

<sup>7</sup>Provided 44.0 mg of tylosin per kilogram of complete diet.

<sup>8</sup>In diets containing ractopamine HCl, the premix, which was added at the expense of corn, provided 10 ppm ractopamine HCl per kilogram of the complete diet.

**Table 2.** Fatty acid profiles of the supplemental oils and fats

Fatty acid, %	CLA oil	Soybean oil	Choice white grease	Beef tallow
14:0	0.07	0.08	1.96	4.50
16:0	6.20	11.36	29.26	30.56
16:1n-7	0.08	0.11	3.36	0.31
18:0	4.92	4.36	19.46	17.17
18:1n-9	25.08	23.86	21.69	45.81
18:1n-7	0.38	0.43	10.68	0.53
18:2n-6	1.19	51.27	13.19	0.24
18:2 <i>cis</i> -9 <i>trans</i> -11	30.10	0.56	0.01	0.02
18:2 <i>trans</i> -10 <i>cis</i> -12	31.41	0.14	0.03	ND
18:2 <i>cis</i> -9 <i>cis</i> -11	ND <sup>1</sup>	ND	ND	0.03
18:2 <i>trans</i> -9 <i>trans</i> -11	0.02	ND	ND	ND
18:3n-6	ND	0.01	ND	0.13
18:3n-3	0.11	7.28	0.20	0.61
20:1n-9	0.29	1.18	0.10	0.02
20:4n-6	0.05	ND	0.01	0.02
20:5n-3	0.10	0.36	0.03	0.06
Iodine value	130.94	130.14	54.49	46.06

<sup>1</sup>ND = not detected.

a 1-cm wide bar. Bacon length was analyzed as the length measured between the anterior and the posterior end of the belly when it was suspended over the bar. Therefore, firmer bellies would give greater values of the length measured between the anterior and posterior ends when suspended over the bar. Additionally, belly firmness scores (range 1 to 5) were assigned to the bellies; a score of 5 was assigned to the firmest bellies, and a score of 1 was assigned to the softest bellies. The scores were assigned by personnel with no knowledge of the dietary treatments.

### *Carcass and Belly Characteristics of the Subset of the Gilts Removed After Phase 1*

The following measurements were taken on the subset (n = 48) of pigs that was slaughtered at the completion of the first phase of the experiment: HCW, backfat depth at the 10th rib, loin eye area, and belly firmness score. The procedures used to obtain these measurements were the same as those used to analyze the carcass quality of the pigs harvested at the completion of the trial, which were outlined previously.

**Table 3.** The effects of CLA and dietary fat type on pig growth performance (wk 0 to 4)

Item	CLA <sup>1</sup>		Fat-type <sup>2</sup>			SEM	P-value	
	CLA	SBO	0%	CWG	BT		CLA	Fat
ADG, kg								
wk 0 to 2	0.985	0.947	0.919	1.017	0.963	0.03	0.35	0.11
wk 2 to 4	0.931	0.938	0.911	0.936	0.957	0.05	0.76	0.88
wk 0 to 4	0.958	0.942	0.915	0.976	0.960	0.03	0.27	0.15
ADFI, kg								
wk 0 to 2	2.342	2.317	2.356	2.359	2.273	0.06	0.99	0.56
wk 2 to 4	2.393	2.499	2.487	2.430	2.422	0.07	0.22	0.15
wk 0 to 4	2.367	2.408	2.421	2.394	2.348	0.05	0.46	0.38
G:F								
wk 0 to 2	0.422	0.410	0.390 <sup>x</sup>	0.433 <sup>y</sup>	0.425 <sup>y</sup>	0.01	0.23	0.01
wk 2 to 4	0.388	0.376	0.365	0.386	0.396	0.01	0.42	0.09
wk 0 to 4	0.405	0.394	0.378 <sup>x</sup>	0.410 <sup>y</sup>	0.411 <sup>y</sup>	0.01	0.18	0.01
Initial BW, kg	58.95	59.25	58.96	59.09	59.27	0.30	0.72	0.80
Final BW, kg	85.76	85.57	84.35	85.94	86.27	0.81	0.89	0.18

<sup>x,y</sup>Within a row, means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 228 pigs; diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>2</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

### Lipid and Fatty Acid Analysis

Samples of LM, belly, and inner middle and outer layers of subcutaneous backfat were collected and freeze-dried. Samples were stored and then extracted and prepared for gas chromatography all at once so that variation in method and instrumentation would be minimized. Lipids were extracted from freeze-dried tissue aliquots by the method of Bligh and Dyer (1959) with modifications as we have described (Eggert et al., 2001). Lipid concentrations (milligram lipid per gram dry weight of tissue) were quantified; then lipid extracts were frozen ( $-80^{\circ}\text{C}$ ). Fatty acid methyl esters were prepared by incubating extracts with tetramethylguanidine at  $95^{\circ}\text{C}$  (Shantha et al., 1993). Methyl esters were separated and quantified by gas-liquid

chromatography using a 30-m Omega-wax 320 capillary column (Supelco Chromatography Products, Bellefonte, PA). Helium flow rate was 30 mL/min; oven temperature was  $175^{\circ}\text{C}$  for 4 min and increased to  $220^{\circ}\text{C}$  at a rate of  $3^{\circ}\text{C}/\text{min}$ . Identification of fatty acid methyl esters was accomplished by comparing retention times of peaks of unknown origin with peaks of retention times of authentic standards spiked with methyl esters of CLA isomers (c9t11-CLA, t10c12-CLA, c9c11-CLA, t9t11-CLA, Matreya Inc., Pleasant Gap, PA). Data were integrated using Chemstation Software (Packard Instrument Company, Meriden, CT). Iodine values (**IOV**) were calculated for the fatty acid composition of the various fat depots according to the AOAC (1990) equation:  $\text{IOV} = (\% \text{ hexadecenoic acid} \times 0.950) + (\% \text{ octadecenoic acid} \times 0.860) + (\%$

**Table 4.** The effect of ractopamine (Rac), CLA, and dietary fat type on pig growth performance (wk 4 to 8)

Item	Rac <sup>1</sup>		CLA <sup>2</sup>		Fat type <sup>3</sup>			SEM	P-value		
	0 ppm	10 ppm	CLA	SBO	0%	CWG	BT		Rac	CLA	Fat
ADG, kg											
wk 4 to 6	0.934	1.162	1.037	1.059	1.056	1.018	1.071	0.05	0.01	0.46	0.63
wk 6 to 8	0.818	0.938	0.915	0.841	0.859	0.884	0.891	0.08	0.01	0.03	0.41
wk 4 to 8	0.870	1.050	0.976	0.944	0.948	0.951	0.981	0.05	0.01	0.22	0.51
ADFI, kg											
wk 4 to 6	2.497	2.504	2.493	2.508	2.567	2.445	2.491	0.09	0.91	0.80	0.13
wk 6 to 8	2.430	2.518	2.468	2.480	2.592 <sup>x</sup>	2.411 <sup>y</sup>	2.419 <sup>y</sup>	0.14	0.21	0.86	0.02
wk 4 to 8	2.464	2.511	2.481	2.494	2.579 <sup>x</sup>	2.428 <sup>y</sup>	2.455 <sup>y</sup>	0.10	0.37	0.80	0.02
G:F											
wk 4 to 6	0.369	0.464	0.415	0.418	0.402	0.416	0.430	0.02	0.01	0.82	0.12
wk 6 to 8	0.338	0.372	0.371	0.339	0.330 <sup>x</sup>	0.367 <sup>y</sup>	0.368 <sup>y</sup>	0.02	0.01	0.01	0.01
wk 4 to 8	0.353	0.418	0.393	0.378	0.366 <sup>x</sup>	0.392 <sup>y</sup>	0.399 <sup>y</sup>	0.01	0.01	0.02	0.01
Initial BW, kg	86.28	85.05	85.76	85.57	84.35	86.39	86.27	1.1	0.40	0.90	0.20
Final BW, kg	110.55	114.45	112.92	112.08	110.89	112.91	113.70	1.7	0.01	0.54	0.10

<sup>x,y</sup>Within a row, means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>Ractopamine treatments were imposed at the completion of wk 4 of the experiment, n = 180 pigs.

<sup>2</sup>Diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>3</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

**Table 5.** The effects of CLA and dietary fat type on carcass characteristics at wk 4

Item	CLA <sup>1</sup>		Fat-type <sup>2</sup>			SEM	P-value	
	CLA	SBO	0%	CWG	BT		CLA	Fat
Carcass wt, kg	53.75	51.66	52.41	54.55	51.16	1.9	0.60	0.99
Dressing percent	71.74	71.91	72.14	71.40	71.94	1.1	0.20	0.67
10th rib backfat, mm	11.97	12.98	12.39	12.49	12.55	1.1	0.20	0.31
Loin eye area, cm <sup>2</sup>	34.34	33.65	33.64	34.64	33.70	1.2	0.47	0.77
Belly firmness score	2.79	2.81	2.50	2.84	3.07	0.3	0.71	0.19

<sup>1</sup>n = 48 pigs; diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>2</sup>Dietary fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

octadecadienoic acid  $\times 1.732$ ) + (% octadecatrienoic acid  $\times 2.616$ ) + (% eicosenoic acid  $\times 0.785$ ) + (% docosenoic acid  $\times 0.723$ ).

### Statistical Analysis

Data were analyzed as a randomized complete block design using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). For the first phase of the experiment (wk 0 to 4), and for the subset of pigs that was slaughtered at the completion of phase 1, a  $2 \times 3$  factorial arrangement consisting of the 2 CLA levels (0 and 0.6%) and the 3 fat levels (0%, CWG, and BT) was

used. Performance data from the second phase of the trial (wk 4 to 8) and carcass data collected at the completion of the experiment were analyzed as a  $2 \times 2 \times 3$  factorial arrangement of treatments that included the level of ractopamine hydrochloride (0 or 10 ppm), the 2 levels of CLA treatment, and the 3 levels of dietary fat treatment. Pen served as the experimental unit for the performance and carcass data. Belly weights and belly lengths were used as covariates in the objective belly firmness analysis. The models included the effects of ractopamine, CLA, dietary fat treatments, and all 2- and 3-way interactions. The residual mean square error term was used as the error

**Table 6.** The effect of ractopamine (Rac), CLA, and dietary fat-type on carcass characteristics at wk 8

Item	Rac <sup>1</sup>		CLA <sup>2</sup>		Fat type <sup>3</sup>			SEM	P-value		
	0 ppm	10 ppm	CLA	SBO	0%	CWG	BT		Rac	CLA	Fat
Carcass weight, kg	78.93	82.83	80.92	80.84	79.41 <sup>x</sup>	81.65 <sup>y</sup>	81.59 <sup>y</sup>	0.6	0.01	0.92	0.02
Dressing percent, %	71.00	72.42	71.49	71.92	71.23	71.95	71.94	0.6	0.01	0.22	0.16
Lean percentage, <sup>4</sup> %	56.24	57.79	57.53	56.50	56.92	56.74	57.39	0.4	0.01	0.03	0.49
Backfat depth, mm											
10th rib inner layer	9.39	8.89	8.89	9.39	8.89	9.91	8.64	0.5	0.35	0.39	0.10
10th rib outer layer	8.38	7.87	7.87	8.64	7.87 <sup>x</sup>	8.59 <sup>y</sup>	8.08 <sup>x</sup>	0.2	0.01	0.01	0.05
10th rib	17.91	16.76	16.76	18.03	16.76 <sup>x,y</sup>	18.54 <sup>x</sup>	16.76 <sup>y</sup>	0.5	0.10	0.06	0.02
Last rib	19.56	19.30	18.54	20.32	18.29 <sup>x</sup>	20.83 <sup>y</sup>	19.30 <sup>x</sup>	0.5	0.50	0.01	0.01
LM											
Area, cm <sup>2</sup>	46.12	51.28	49.61	47.86	47.09 <sup>x</sup>	49.67 <sup>y</sup>	49.41 <sup>y</sup>	0.8	0.01	0.06	0.05
pH at 45 min <sup>5</sup>	6.47	6.50	6.48	6.49	6.46	6.50	6.50	0.02	0.59	0.71	0.42
pH at 24 h	5.63	5.62	5.62	5.63	5.62	5.61	5.64	0.02	0.88	0.74	0.55
Color <sup>6</sup>	2.74	2.76	2.78	2.72	2.76	2.76	2.72	0.06	0.88	0.37	0.84
Marbling <sup>6</sup>	1.03	1.03	1.05	1.01	1.00	1.03	1.07	0.02	0.99	0.10	0.14
Firmness <sup>6</sup>	2.65	2.74	2.71	2.68	2.71	2.67	2.71	0.06	0.22	0.74	0.84
Drip loss, 24 h	2.84	2.76	2.71	2.91	2.76	2.78	2.89	0.22	0.75	0.38	0.88
Lipid content, %	2.44	1.92	2.21	2.15	2.05	2.24	2.25	0.16	0.01	0.72	0.62
Moisture, %	71.61	71.63	71.62	71.62	71.85	71.38	71.63	0.25	0.94	0.99	0.41
Belly firmness score <sup>7</sup>	3.04	2.74	3.11	2.67	2.96	2.97	2.74	0.12	0.07	0.01	0.41
Belly length, <sup>8</sup> cm	3.30	3.11	3.45	2.96	3.29	3.39	2.93	0.16	0.30	0.01	0.10

<sup>x,y</sup>Within a row, means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 180 pigs; Rac treatments were imposed at the completion of wk 4 of the experiment.

<sup>2</sup>Diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>3</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

<sup>4</sup>Lean percentage was calculated from the NPPC (1991) equations for ribbed carcasses.

<sup>5</sup>Interaction of ractopamine and CLA treatments ( $P < 0.05$ ).

<sup>6</sup>NPPC (1999) scoring system. Color: 1 = pale, pinkish gray, 6 = dark, purplish red. Marbling: 1 = devoid to practically devoid, 10 = moderately abundant or greater. Firmness: 1 = very soft and very watery, 5 = very firm and dry.

<sup>7</sup>Suspension angle (1 = soft, unsliceable; 5 = very firm).

<sup>8</sup>Objective firmness was analyzed as the length measured between the anterior and the posterior end of the belly when it was suspended over a 1-cm wide bar. Belly weights and belly lengths were used as covariates in the analysis of belly firmness.

**Table 7.** The effects of CLA and dietary fat type on fatty acid profiles of pig bellies at wk 4

Fatty acid, %	CLA <sup>1</sup>		Fat-type <sup>2</sup>			SEM	P-value	
	CLA	SBO	0%	CWG	BT		CLA	Fat
14:0	1.76	1.34	1.56	1.49	1.60	0.06	0.01	0.35
16:0	27.28	25.18	26.68	25.94	26.07	0.36	0.01	0.31
16:1n-7	2.69	2.40	2.63	2.40	2.60	0.19	0.21	0.68
18:0	15.92	13.41	14.91	14.66	14.42	0.36	0.01	0.62
18:1n-9	36.99	42.05	38.68	39.96	39.93	0.52	0.01	0.15
18:1n-7	3.17	3.39	3.11	3.30	3.42	0.09	0.04	0.07
18:2n-6	8.86	10.05	9.30	9.78	9.29	0.36	0.01	0.55
18:2 <i>cis</i> -9 <i>trans</i> -11	—	—	—	—	—	—	0.01	0.04
18:2 <i>trans</i> -10 <i>cis</i> -12	0.33	0.02	0.17	0.17	0.18	0.02	0.01	0.99
18:2 <i>cis</i> -9 <i>cis</i> -11	0.07	0.03	0.06	0.04	0.04	0.01	0.01	0.08
18:2 <i>trans</i> -9 <i>trans</i> -11 <sup>3</sup>	—	—	—	—	—	—	0.01	0.01
0%	0.07 <sup>e</sup>	0.00 <sup>h</sup>	—	—	—	0.01	—	—
CWG	0.05 <sup>f</sup>	0.01 <sup>h</sup>	—	—	—	—	—	—
BT	0.09 <sup>g</sup>	0.00 <sup>h</sup>	—	—	—	—	—	—
18:3n-6	0.02	0.06	0.02	0.02	0.07	0.03	0.35	0.43
18:3n-3	0.36	0.48	0.42	0.45	0.39	0.03	0.01	0.29
20:1n-9	0.70	0.84	0.76	0.81	0.73	0.02	0.01	0.09
20:4n-6	0.36	0.35	0.35	0.34	0.39	0.04	0.89	0.65
20:5n-3	0.04	0.13	0.03	0.08	0.14	0.06	0.19	0.42
Total CLA	1.15	0.20	0.64	0.63	0.76	0.06	0.01	0.28
Total SFA	44.96	39.92	43.15	42.09	42.08	0.56	0.01	0.31
Total MUFA	43.54	48.68	45.18	46.47	46.68	0.66	0.01	0.24
Total PUFA	10.96	11.40	10.93	11.42	11.18	0.41	0.37	0.72
Total UFA <sup>4</sup>	54.88	60.07	56.68	57.89	57.86	0.54	0.01	0.24
Iodine value	56.18	60.89	57.73	59.10	58.77	0.65	0.01	0.33

<sup>e,f,g,h</sup>Within the CLA × SBO interaction, simple-effect means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 48 pigs; diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>2</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

<sup>3</sup>Interaction of CLA and dietary-fat treatments ( $P < 0.05$ ).

<sup>4</sup>UFA = unsaturated fatty acids.

term to test the main effects and interactions. Means were evaluated using the PDIF and STDERR options of GLM.

## RESULTS

### Growth Performance

Pigs fed diets containing 5% added fat had greater ( $P < 0.01$ ) G:F for wk 0 to 2 and tended to have greater G:F for wk 2 to 4 than gilts fed diets containing 0% added fat (Table 3). Furthermore, feeding diets containing 5% added fat elicited an increase ( $P < 0.01$ ) in G:F during the first phase (wk 0 to 4) of the experiment. Pigs fed diets containing ractopamine had greater ( $P < 0.01$ ) ADG and G:F than pigs fed diets devoid of ractopamine during wk 4 to 6, wk 6 to 8, and during the entire period in which the ractopamine treatment was imposed (wk 4 to 8; Table 4). Pigs fed diets containing CLA had increased ( $P < 0.03$ ) ADG during wk 4 to 6 and increased G:F wk 6 to 8 ( $P < 0.01$ ) and wk 4 to 8 ( $P < 0.02$ ). Pigs fed diets containing 5% added fat had decreased ( $P < 0.02$ ) ADFI during wk 6 to 8 and wk 4 to 8 and, therefore, demonstrated greater ( $P < 0.01$ ) G:F during the same periods than gilts fed diets containing 0% added fat. Pigs fed ractopamine had greater ( $P < 0.01$ ) BW at the completion of the experi-

ment than pigs fed diets devoid of ractopamine. Furthermore, feeding diets containing 5% added fat tended ( $P = 0.10$ ) to increase final BW.

### Carcass Characteristic, Loin Quality, and Belly Firmness

Neither CLA nor added fat affected the carcass characteristics or belly firmness of the pigs slaughtered after phase 1 of the experiment (wk 4; Table 5). Feeding either diets containing ractopamine or diets containing 5% added fat increased ( $P < 0.02$ ) carcass weight (Table 6). Carcasses from pigs fed ractopamine had greater ( $P < 0.01$ ) dressing percentages than carcasses from pigs fed no ractopamine. The predicted lean percentage was affected by both ractopamine and CLA treatments; carcasses from pigs fed ractopamine had a greater ( $P < 0.01$ ) predicted percent lean than pigs fed diets devoid of ractopamine, and pigs fed 0.6% CLA had a greater ( $P < 0.03$ ) predicted lean percentage than gilts fed 0% CLA. Outer layer backfat depth at the 10th rib was decreased ( $P < 0.01$ ) by feeding either ractopamine or CLA and was increased ( $P = 0.05$ ) by adding fat as CWG to the diets. Feeding ractopamine or CLA tended ( $P = 0.10$ ) to decrease 10th rib backfat, whereas feeding fat in the form of CWG increased ( $P < 0.02$ ) 10th rib backfat compared with pigs fed BT.

**Table 8.** The effects of CLA and dietary fat type on fatty acid profiles of inner-layer backfat at wk 4

Fatty acid, %	CLA <sup>1</sup>		Fat-type <sup>2</sup>			SEM	P-value	
	CLA	SBO	0%	CWG	BT		CLA	Fat
14:0	1.75	1.28	1.55	1.45	1.54	0.11	0.01	0.76
16:0	25.39	24.46	25.92	24.52	24.34	0.79	0.34	0.32
16:1n-7	2.19	2.11	2.17	2.00	2.28	0.11	0.58	0.28
18:0	15.47	14.11	14.65	15.35	14.38	0.63	0.10	0.58
18:1n-9	36.11	39.86	37.17	37.93	38.86	0.94	0.01	0.49
18:1n-7	2.39	2.37	2.43	2.43	2.29	0.10	0.86	0.60
18:2n-6	12.51	12.82	12.78	12.65	12.57	0.80	0.75	0.98
18:2 <i>cis</i> -9 <i>trans</i> -11	1.25	0.30	0.68	0.79	0.87	0.13	0.01	0.58
18:2 <i>trans</i> -10 <i>cis</i> -12	0.59	0.06	0.28	0.36	0.33	0.07	0.01	0.71
18:2 <i>cis</i> -9 <i>cis</i> -11	0.08	0.06	0.08	0.07	0.06	0.02	0.29	0.69
18:2 <i>trans</i> -9 <i>trans</i> -11	ND <sup>3</sup>	ND	ND	ND	ND	—	—	—
18:3n-6	0.07	0.08	0.07 <sup>x</sup>	0.08 <sup>x</sup>	0.09 <sup>y</sup>	0.003	0.13	0.01
18:3n-3	0.74	0.89	0.75	0.80	0.90	0.11	0.24	0.64
20:1n-9	0.82	0.92	0.83	0.95	0.84	0.04	0.05	0.10
20:4n-6	0.25	0.29	0.26	0.26	0.29	0.02	0.08	0.52
20:5n-3	0.02	0.03	0.02	0.02	0.03	0.01	0.12	0.38
Total CLA	1.92	0.42	1.04	1.22	1.26	0.21	0.01	0.73
Total SFA	42.61	39.85	42.12	41.31	40.26	1.43	0.13	0.68
Total MUFA	41.52	45.26	42.60	43.31	44.26	0.95	0.01	0.50
Total PUFA	15.86	14.92	15.29	15.41	15.47	0.78	0.32	0.99
Total UFA <sup>4</sup>	57.37	60.18	57.89	58.71	59.73	1.43	0.12	0.68
Iodine value	62.76	64.31	62.65	63.41	64.55	1.87	0.49	0.79

<sup>x,y</sup>Within a row, means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 48 pigs; diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>2</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

<sup>3</sup>ND = not detected.

<sup>4</sup>UFA = unsaturated fatty acids.

Backfat depth at the last rib was decreased ( $P < 0.01$ ) by feeding CLA and was increased ( $P < 0.05$ ) in pigs fed CWG compared with pigs fed either BT or 0% added fat.

Feeding diets containing ractopamine or 5% added fat increased LM area ( $P < 0.05$ ), and feeding CLA tended ( $P = 0.06$ ) to increase LM area. There was an interaction ( $P < 0.05$ ) between ractopamine and CLA treatments for LM pH at 45 min postslaughter. There was no difference in 45-min pH between CLA treatment groups in gilts fed no ractopamine (6.50 for CLA and 6.45 control). However, within the treatment group that was fed ractopamine, those pigs that were fed CLA had decreased (6.45 vs. 6.53,  $P < 0.05$ ) pH at 45 min postslaughter. There was a trend ( $P = 0.10$ ) toward greater marbling scores for gilts fed CLA compared with pigs fed no added CLA. The lipid content of the LM was decreased ( $P < 0.01$ ) by feeding ractopamine. Subjective belly firmness was increased ( $P < 0.01$ ) by feeding CLA and tended to be decreased ( $P = 0.07$ ) by ractopamine treatment. The objective measurement of belly firmness was likewise increased ( $P < 0.01$ ) by feeding CLA.

### Fatty Acid Composition

After the first phase of the experiment (wk 4), bellies from pigs fed CLA had more ( $P < 0.01$ ) total CLA, more SFA ( $P < 0.01$ ), less MUFA ( $P < 0.01$ ), and less total

UFA ( $P < 0.01$ ) than pigs fed no added CLA (Table 7). Likewise, the IOV of bellies from pigs fed CLA was decreased ( $P < 0.01$ ). The fatty acid concentrations measured in the belly were altered by dietary CLA except 16:1n-7, 18:3n-6, 20:4n-6, and 20:5n-3. This is reflected by the lack of difference found in total PUFA content of the bellies from pigs fed CLA. Inner-layer backfat from pigs fed CLA for a period of 4 wk had more ( $P < 0.01$ ) total CLA and decreased ( $P < 0.01$ ) MUFA compared with pigs fed no added CLA (Table 8). Feeding fat in the form of BT increased ( $P < 0.01$ ) the content of 18:3n-6 but did not alter the abundance of any other fatty acids from inner-layer backfat. For outer-layer backfat, the CLA content was increased ( $P < 0.01$ ), and the abundance of MUFA was decreased ( $P < 0.01$ ) by feeding CLA (Table 9). An interaction ( $P < 0.05$ ) between CLA and dietary fat-type was found for 20:5n-3. Within the treatment group fed CLA, there was no difference between dietary fat-type for the abundance of 20:5n-3, but for pigs fed diets containing added CLA there was an increase ( $P < 0.05$ ) in the abundance of 20:5n-3 in pigs fed CWG compared with pigs fed 0% added fat or CWG.

At the completion of the experiment (wk 8), bellies from pigs fed CLA had increased ( $P < 0.01$ ) total CLA and SFA and had decreased ( $P < 0.01$ ) MUFA and UFA (Table 10). In contrast, feeding 5% fat in the form of CWG or BT decreased ( $P < 0.01$ ) SFA and increased ( $P < 0.01$ ) the MUFA and UFA content of the belly fat.

**Table 9.** The effects of CLA and dietary fat type on fatty acid profiles of outer-layer backfat at wk 4

Fatty acid, %	CLA <sup>1</sup>		Fat-type <sup>2</sup>			SEM	P-value	
	CLA	SBO	0%	CWG	BT		CLA	Fat
14:0	1.70	1.37	1.62	1.44	1.55	0.10	0.01	0.47
16:0	24.55	23.93	25.14	23.68	23.92	0.86	0.52	0.43
16:1n-7	2.35	2.71	2.88	2.38	2.33	0.33	0.35	0.43
18:0	13.27	11.47	11.90	12.79	12.42	0.82	0.07	0.73
18:1n-9	39.14	42.54	39.69	41.21	41.63	1.1	0.01	0.38
18:1n-7	2.40	2.58	2.59	2.41	2.48	0.15	0.34	0.73
18:2n-6	13.08	13.00	13.38	13.08	12.67	0.79	0.93	0.81
18:2 <i>cis</i> -9 <i>trans</i> -11	0.96	0.19	0.48	0.54	0.70	0.11	0.01	0.35
18:2 <i>trans</i> -10 <i>cis</i> -12	0.46	0.02	0.21	0.26	0.26	0.06	0.01	0.78
18:2 <i>cis</i> -9 <i>cis</i> -11	0.07	0.03	0.05	0.05	0.05	0.01	0.01	0.86
18:2 <i>trans</i> -9 <i>trans</i> -11	ND <sup>3</sup>	ND	ND	ND	ND	—	—	—
18:3n-6	0.08	0.07	0.07	0.07	0.08	0.003	0.89	0.16
18:3n-3	0.62	0.74	0.73	0.64	0.68	0.06	0.10	0.64
20:1n-9 <sup>4</sup>	—	—	—	—	—	—	0.10	0.26
0%	0.84 <sup>f</sup>	0.80 <sup>f</sup>	—	—	—	0.07	—	—
CWG	0.89 <sup>f,g</sup>	0.90 <sup>f,g</sup>	—	—	—	—	—	—
BT	0.77 <sup>f</sup>	1.11 <sup>g</sup>	—	—	—	—	—	—
20:4n-6	0.24	0.24	0.25	0.23	0.23	0.02	0.99	0.83
20:5n-3 <sup>4</sup>	—	—	—	—	—	—	0.01	0.62
0%	0.04 <sup>f</sup>	0.02 <sup>g</sup>	—	—	—	0.01	—	—
CWG	0.03 <sup>f</sup>	0.04 <sup>f</sup>	—	—	—	—	—	—
BT	0.05 <sup>f</sup>	0.01 <sup>g</sup>	—	—	—	—	—	—
Total CLA	1.49	0.24	0.74	0.84	1.00	0.18	0.01	0.54
Total SFA	39.52	36.78	38.66	37.91	37.88	1.6	0.16	0.92
Total MUFA	44.72	48.77	45.97	46.89	47.38	1.1	0.01	0.65
Total PUFA	15.65	14.43	15.31	15.03	14.79	0.72	0.17	0.88
Total UFA <sup>5</sup>	60.38	63.20	61.27	61.92	62.17	1.6	0.17	0.92
Iodine value	65.28	66.73	65.89	66.04	66.08	2.01	0.55	0.99

<sup>f,g</sup>Within the CLA × SBO interaction, simple-effect means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 48 pigs; diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>2</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

<sup>3</sup>ND = not detected.

<sup>4</sup>Interaction of CLA and dietary-fat treatments ( $P < 0.05$ ).

<sup>5</sup>UFA = unsaturated fatty acids.

The IOV of the bellies was decreased ( $P < 0.01$ ) by feeding CLA and was increased ( $P < 0.01$ ) by adding fat to the diet. Feeding ractopamine tended ( $P < 0.06$ ) to decrease the content of SFA and decreased ( $P < 0.05$ ) the abundance of 18:00 in bellies. Inner-layer backfat from pigs fed CLA had greater ( $P < 0.01$ ) total CLA, decreased ( $P < 0.01$ ) MUFA, and decreased ( $P < 0.01$ ) UFA compared with pigs fed no added CLA (Table 11).

Adding 5% fat to the diets increased ( $P < 0.05$ ) the abundance of MUFA and UFA in inner-layer backfat. There were interactions ( $P < 0.05$ ) between CLA and added-fat treatments for both MUFA and UFA. The magnitude of the increase in MUFA and UFA found in pigs fed fat was greater ( $P < 0.05$ ) in pigs fed diets containing CLA compared with those fed no added CLA. Inner-layer backfat from pigs fed ractopamine had a greater ( $P < 0.02$ ) UFA content and tended ( $P < 0.07$ ) to have a greater PUFA content. Feeding CLA decreased ( $P < 0.01$ ), and feeding ractopamine or 5% added fat, as CWG or BT, increased the IOV of inner-layer backfat. The outer-layer backfat of gilts fed CLA had increased ( $P < 0.01$ ) total CLA and SFA and de-

creased ( $P < 0.01$ ) MUFA and UFA compared with pigs fed no added CLA (Table 12).

Unlike inner-layer backfat, feeding CLA increased ( $P < 0.01$ ) the abundance of 18:0. Adding 5% fat to the diets decreased ( $P < 0.01$ ) SFA and increased ( $P < 0.01$ ) MUFA and UFA of outer-layer backfat. Feeding fat in the form of BT decreased ( $P < 0.01$ ) the abundance of 20:1n-9 compared with feeding fat in the form of CWG. There was an interaction ( $P < 0.05$ ) between CLA and fat-type for total the CLA content of outer-layer backfat. Pigs within the group fed no added CLA had an increase ( $P < 0.05$ ) in the abundance of CLA when fed BT, but BT did not increase the total CLA content of outer-layer backfat when the pigs were fed added CLA. Ractopamine tended ( $P = 0.07$ ) to increase the total CLA content and the abundance of 18:2n-6 and increased ( $P < 0.03$ ) the abundance of 20:5n-3 in outer-layer backfat. The IOV of outer-layer backfat was decreased ( $P < 0.01$ ) by feeding CLA, tended ( $P = 0.07$ ) to be increased by feeding ractopamine, and was increased ( $P < 0.02$ ) by adding 5% animal fat to the diet. The LM of gilts fed CLA had a greater ( $P < 0.01$ ) content

**Table 10.** Effects of ractopamine (Rac), CLA, and dietary fat type on fatty acid profiles of belly fat in pigs at wk 8

Fatty acid, %	Rac <sup>1</sup>		CLA <sup>2</sup>		Fat type <sup>3</sup>			SEM	P-value		
	0 ppm	10 ppm	CLA	SBO	0%	CWG	BT		Rac	CLA	Fat
14:0	1.76	1.76	2.07	1.45	1.80	1.66	1.83	0.08	0.94	0.01	0.29
16:0	26.19	25.59	27.29	24.49	27.52 <sup>x</sup>	25.25 <sup>y</sup>	24.90 <sup>y</sup>	0.37	0.16	0.01	0.01
16:1n-7	2.54	2.62	2.57	2.58	2.69	2.45	2.58	0.08	0.36	0.91	0.10
18:0	15.42	14.73	17.03	13.12	15.71 <sup>x</sup>	14.73 <sup>y</sup>	14.78 <sup>y</sup>	0.29	0.05	0.01	0.04
18:1n-9	37.84	37.81	34.01	41.64	36.55 <sup>x</sup>	38.64 <sup>y</sup>	38.28 <sup>y</sup>	0.47	0.96	0.01	0.01
18:1n-7	2.98	3.12	2.87	3.23	2.94	3.11	3.10	0.07	0.06	0.01	0.12
18:2n-6	10.23	10.58	9.70	11.12	9.82	11.04	10.35	0.37	0.42	0.01	0.07
18:2 <i>cis</i> -9 <i>trans</i> -11	0.75	0.85	1.35	0.25	0.81 <sup>x,y</sup>	0.71 <sup>x</sup>	0.88 <sup>y</sup>	0.04	0.08	0.01	0.04
18:2 <i>trans</i> -10 <i>cis</i> -12	0.32	0.35	0.62	0.05	0.36	0.31	0.33	0.03	0.31	0.01	0.49
18:2 <i>cis</i> -9 <i>cis</i> -11	0.06	0.06	0.09	0.03	0.07 <sup>x</sup>	0.06 <sup>y</sup>	0.06 <sup>y</sup>	0.002	0.29	0.01	0.04
18:2 <i>trans</i> -9 <i>trans</i> -11	0.03	0.04	0.06	0.01	0.04	0.03	0.04	0.01	0.63	0.01	0.88
18:3n-6	0.02	0.02	0.01	0.03	0.02	0.02	0.02	0.005	0.13	0.01	0.66
18:3n-3	0.54	0.57	0.44	0.67	0.49 <sup>x</sup>	0.60 <sup>y</sup>	0.58 <sup>y</sup>	0.02	0.18	0.01	0.01
20:1n-9	0.74	0.77	0.69	0.82	0.73 <sup>x</sup>	0.81 <sup>y</sup>	0.73 <sup>x</sup>	0.02	0.40	0.01	0.02
20:4n-6	0.26	0.33	0.30	0.29	0.27	0.31	0.31	0.02	0.01	0.83	0.33
20:5n-3	0.09	0.08	0.07	0.09	0.07	0.07	0.10	0.02	0.59	0.47	0.42
Total CLA	1.17	1.30	2.19	0.34	1.27	1.12	1.31	0.08	0.14	0.01	0.18
Total SFA	43.37	42.08	46.39	39.06	45.02 <sup>x</sup>	41.64 <sup>y</sup>	41.51 <sup>y</sup>	0.59	0.06	0.01	0.01
Total MUFA	44.09	44.32	40.14	48.27	42.91 <sup>x</sup>	45.01 <sup>y</sup>	44.69 <sup>y</sup>	0.54	0.73	0.01	0.02
Total PUFA	12.41	12.99	12.74	12.66	12.05	13.28	12.76	0.41	0.22	0.86	0.12
Total UFA <sup>4</sup>	57.30	56.50	52.88	60.92	54.96 <sup>x</sup>	58.29 <sup>y</sup>	57.45 <sup>y</sup>	0.58	0.23	0.01	0.01
Iodine value	58.99	60.15	56.12	63.03	57.36 <sup>x</sup>	61.24 <sup>y</sup>	60.11 <sup>y</sup>	0.73	0.17	0.01	0.01

<sup>x,y</sup>Within a row, means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 180 pigs; Rac treatments were imposed at the completion of wk 4 of the experiment.

<sup>2</sup>Diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>3</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

<sup>4</sup>UFA = unsaturated fatty acids.

of total CLA and SFA, and a decreased ( $P < 0.01$ ) content of PUFA and UFA (Table 13).

There was a trend ( $P = 0.08$ ) toward decreased MUFA in LM from pigs fed CLA. Feeding CLA decreased ( $P < 0.01$ ) the IOV of LM. For 20:4n-6 there were interactions ( $P < 0.05$ ) between ractopamine and added-fat type and between CLA and added fat type. Feeding BT increased ( $P < 0.05$ ) the abundance of 20:4n-6 in pigs fed diets devoid of ractopamine but did not increase 20:4n-6 in LM from pigs fed ractopamine. Feeding BT increased ( $P < 0.05$ ) 20:4n-6 in pigs fed diets containing no added CLA, but not in pigs fed diets containing CLA.

## DISCUSSION

The current study examined the effects of ractopamine, CLA, and rendered animal fats on growth performance, carcass characteristics, and fatty acid profiles of genetically lean pigs. As found in previous studies, both ractopamine (Williams et al., 1994; Stoller et al., 2003) and fat (Williams et al., 1994) increased ADG and G:F. Adding CLA to the diets increased ADG for a portion of the experiment (wk 6 to 8) and increased G:F during the second phase of the experiment. The increase in G:F agrees with other studies in which feeding CLA has been found to enhance G:F (Dugan et al., 1997; Ostrowska et al., 1999). The increase in G:F found in pigs fed CLA is likely due to a decrease in fat deposition and a corresponding increase in muscle

protein accretion. In the current study, it was found that CLA tended to decrease backfat depth and increase LM area, but not significantly. Indeed, other investigators (Dugan et al., 1997; Swan et al., 2001) have found that feeding pigs diets containing CLA increased the weight of the LM.

Mechanistically, CLA may decrease adiposity of pigs through its ability to depress the activity of steroyl coenzyme A desaturase in porcine adipose tissue (Smith et al., 2002). Indeed, the increased abundance of saturated fatty acids found in the tissues of pigs fed CLA may be reflective of a decrease in desaturase activity. Furthermore, an increase in the expression of the stearyl-coA desaturase gene is associated with adipocyte hypertrophy (Smith et al., 1999). Another mechanism via which CLA may decrease adiposity in the pig is by the induction of adipocyte apoptosis. Feeding diets containing CLA to mice increased apoptosis in white adipose tissue (Miner et al., 2001). This apoptotic effect in mouse adipose tissue was attributed to consumption of the *trans*-10, *cis*-12 isomer of CLA (Hargrave et al., 2002). Treating 3T3-L1 adipocytes with CLA inhibited proliferation but stimulated the filling of the cells with lipid (Satory and Smith, 1999). The inhibition of adipocyte proliferation might have been due to apoptosis, but apoptosis was not measured. Additionally, treating the 3T3-L1 adipocytes with CLA increased the cellular content of palmitic acid, indicating that CLA stimulated de novo lipogenesis. It is interesting that in our study the abundance of palmitic

**Table 11.** Effects of ractopamine (Rac), CLA, and dietary fat type on fatty acid profiles of inner-layer backfat in pigs at wk 8

Fatty acid, %	Rac <sup>1</sup>		CLA <sup>2</sup>		Fat type <sup>3</sup>			SEM	P-value		
	0 ppm	10 ppm	CLA	SBO	0%	CWG	BT		Rac	CLA	Fat
14:0 <sup>4</sup>	1.74	1.81	—	—	—	—	—	0.06	0.19	0.01	0.01
0%	—	—	2.40 <sup>f</sup>	1.38 <sup>i</sup>	—	—	—	—	—	—	—
CWG	—	—	1.83 <sup>g</sup>	1.36 <sup>i</sup>	—	—	—	—	—	—	—
BT	—	—	2.20 <sup>h</sup>	1.49 <sup>i</sup>	—	—	—	—	—	—	—
16:0	25.46	25.23	26.36	24.33	26.86 <sup>x</sup>	24.74 <sup>y</sup>	24.43 <sup>y</sup>	0.34	0.56	0.01	0.01
16:1n-7	1.40	1.74	1.57	1.58	1.65	1.51	1.55	0.16	0.07	0.95	0.82
18:0	17.33	14.55	16.11	15.77	16.23	15.29	16.29	1.6	0.13	0.86	0.88
18:1n-9	38.37	38.47	34.84	42.00	35.64 <sup>x</sup>	39.73 <sup>y</sup>	39.89 <sup>y</sup>	0.54	0.87	0.01	0.01
18:1n-7	1.75	1.84	1.67	1.92	1.63	1.98	1.77	0.11	0.45	0.04	0.07
18:2n-6	13.02	13.87	12.70	14.19	13.21	13.65	13.47	0.50	0.15	0.01	0.82
18:2 <i>cis</i> -9 <i>trans</i> -11 <sup>4</sup>	1.10	1.20	—	—	—	—	—	0.04	0.04	0.01	0.05
0%	—	—	2.10 <sup>f</sup>	0.23 <sup>h</sup>	—	—	—	—	—	—	—
CWG	—	—	1.89 <sup>f,g</sup>	0.24 <sup>h</sup>	—	—	—	—	—	—	—
BT	—	—	1.96 <sup>g</sup>	0.48 <sup>i</sup>	—	—	—	—	—	—	—
18:2 <i>trans</i> -10 <i>cis</i> -12	0.53	0.55	0.99	0.08	0.57	0.52	0.52	0.03	0.58	0.01	0.34
18:2 <i>cis</i> -9 <i>cis</i> -11	0.13	0.15	0.22	0.06	0.14	0.14	0.13	0.02	0.25	0.01	0.93
18:2 <i>trans</i> -9 <i>trans</i> -11	0.01	0.01	0.01	0.005	0.02	0.003	0.001	0.01	0.92	0.36	0.57
18:3n-6	0.07	0.07	0.07	0.08	0.06 <sup>x</sup>	0.07 <sup>y</sup>	0.08 <sup>z</sup>	0.002	0.06	0.02	0.01
18:3n-3	0.77	0.81	0.64	0.93	0.74	0.82	0.81	0.02	0.10	0.01	0.08
20:1n-9	0.95	0.98	0.95	0.98	0.96	1.00	0.93	0.04	0.61	0.53	0.37
20:4n-6	0.21	0.22	0.19	0.24	0.21 <sup>x</sup>	0.24 <sup>y</sup>	0.20 <sup>x</sup>	0.01	0.75	0.01	0.01
20:5n-3	0.01	0.02	0.02	0.02	0.01 <sup>x</sup>	0.03 <sup>y</sup>	0.02 <sup>x</sup>	0.006	0.36	0.49	0.03
Total CLA	1.76	1.91	3.22	0.46	1.89	1.73	1.88	0.08	0.11	0.01	0.29
Total SFA	44.53	41.59	44.60	41.51	44.98	41.63	42.57	1.6	0.12	0.11	0.33
Total MUFA <sup>4</sup>	42.47	43.03	—	—	—	—	—	0.72	0.34	0.01	0.01
0%	—	—	35.05 <sup>f</sup>	44.71 <sup>h</sup>	—	—	—	—	—	—	—
CWG	—	—	40.79 <sup>g</sup>	47.66 <sup>i</sup>	—	—	—	—	—	—	—
BT	—	—	41.22 <sup>g</sup>	47.07 <sup>i</sup>	—	—	—	—	—	—	—
Total PUFA	15.95	17.02	16.93	16.04	16.56	16.67	16.56	0.51	0.07	0.13	0.82
Total UFA <sup>4,5</sup>	58.42	60.05	—	—	—	—	—	0.80	0.02	0.01	0.01
0%	—	—	51.68 <sup>f</sup>	60.54 <sup>g</sup>	—	—	—	—	—	—	—
CWG	—	—	58.69 <sup>g</sup>	63.09 <sup>h</sup>	—	—	—	—	—	—	—
BT	—	—	57.48 <sup>g</sup>	63.92 <sup>h</sup>	—	—	—	—	—	—	—
Iodine value	63.86	66.24	62.54	67.56	62.14 <sup>x</sup>	66.55 <sup>y</sup>	66.46 <sup>y</sup>	0.83	0.02	0.01	0.01

<sup>f-i</sup>Within the CLA × SBO interaction, simple-effect means with different superscripts differ ( $P < 0.05$ ).

<sup>x,y</sup>Within a row, means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 180 pigs; Rac treatments were imposed at the completion of wk 4 of the experiment.

<sup>2</sup>Diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>3</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

<sup>4</sup>Interaction of CLA and dietary-fat treatments ( $P < 0.05$ ).

<sup>5</sup>UFA = unsaturated fatty acids.

acid was increased in the tissues of pigs fed CLA. This suggests that CLA may stimulate de novo lipogenesis in porcine tissues. However, further research is needed to determine whether CLA induces apoptosis and de novo lipogenesis in porcine adipocytes.

Feeding CLA made the fatty acid composition of the inner-layer backfat less resistant to the changes observed with animal-fat-supplemented diets. The pigs fed CLA had a greater increase in the magnitude of UFA when animal fats were added to the diets. This is intriguing given the findings that CLA typically decreased the content of UFA in porcine tissues (Eggert et al., 2001). It is possible that CLA stimulated lipid filling in this later maturing adipose depot. As previously discussed, treating adipocytes with CLA in vitro induced adipocyte differentiation (Satory and Smith, 1999). Given the high abundance of oleic acid in

rendered animal fats, it is possible that excess dietary lipid may have been incorporated into adipocytes in inner layer adipose tissue when the pigs were fed CLA. However, more research is necessary to determine the effects of CLA on lipid filling in porcine adipocytes in the presence of UFA.

As found in previous studies, feeding ractopamine increased the lean content of pig carcasses (Williams et al., 1994; Stoller et al., 2003), but had relatively little effect on the fatty acid composition of pig tissues when compared with the effects of CLA. As previously found (Stoller et al., 2003), ractopamine decreased the total lipid content of the LM, but did not affect subjective marbling scores. Feeding ractopamine increased the abundance of total UFA found in inner-layer backfat, but did not alter the abundance of palmitic acid. The relative lack of a change in the fatty acid profiles

**Table 12.** Effects of ractopamine (Rac), CLA, and dietary fat-type on fatty acid profiles of outer-layer backfat in pigs at wk 8

Fatty acid, %	Rac <sup>1</sup>		CLA <sup>2</sup>		Fat type <sup>3</sup>			SEM	P-value		
	0 ppm	10 ppm	CLA	SBO	0%	CWG	BT		Rac	CLA	Fat
14:0 <sup>4</sup>	1.78	1.79	—	—	—	—	—	0.06	0.75	0.01	0.01
0%	—	—	2.38 <sup>f</sup>	1.37 <sup>h</sup>	—	—	—	—	—	—	—
CWG	—	—	1.86 <sup>g</sup>	1.33 <sup>h</sup>	—	—	—	—	—	—	—
BT	—	—	2.31 <sup>f</sup>	1.48 <sup>h</sup>	—	—	—	—	—	—	—
16:0	24.40	24.19	25.63	22.96	25.56	23.33	23.99	0.31	0.56	0.01	0.01
16:1n-7	2.19	2.33	2.22	2.30	2.24	2.30	2.24	0.12	0.29	0.60	0.93
18:0	13.62	13.16	15.26	11.52	14.29	12.84	13.04	0.30	0.20	0.01	0.01
18:1n-9	38.96	39.19	36.18	41.97	36.92	39.56	40.75	0.58	0.72	0.01	0.01
18:1n-7	2.25	2.31	2.21	2.35	2.03 <sup>x</sup>	2.40 <sup>y</sup>	2.41 <sup>y</sup>	0.08	0.52	0.14	0.01
18:2n-6	13.33	14.25	12.78	14.81	13.54	14.17	13.67	0.43	0.07	0.01	0.55
18:2 <i>cis</i> -9 <i>trans</i> -11 <sup>4</sup>	1.00	1.08	—	—	—	—	—	0.03	0.05	0.01	0.01
0%	—	—	1.90 <sup>f</sup>	0.16 <sup>h</sup>	—	—	—	—	—	—	—
CWG	—	—	1.62 <sup>g</sup>	0.20 <sup>h</sup>	—	—	—	—	—	—	—
BT	—	—	1.92 <sup>f</sup>	0.44 <sup>i</sup>	—	—	—	—	—	—	—
18:2 <i>trans</i> -10 <i>cis</i> -12 <sup>4</sup>	0.45	0.48	—	—	—	—	—	0.03	0.18	0.01	0.05
0%	—	—	0.96 <sup>f</sup>	0.04 <sup>h</sup>	—	—	—	—	—	—	—
CWG	—	—	0.81 <sup>g</sup>	0.04 <sup>h</sup>	—	—	—	—	—	—	—
BT	—	—	0.89 <sup>f</sup>	0.04 <sup>h</sup>	—	—	—	—	—	—	—
18:2 <i>cis</i> -9 <i>cis</i> -11	0.07	0.07	0.16	0.03	0.07	0.07	0.08	0.004	0.62	0.01	0.12
18:2 <i>trans</i> -9 <i>trans</i> -11	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.003	0.11	0.11	0.09
18:3n-6	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.01	0.46	0.20	0.86
18:3n-3	0.77	0.80	0.64	0.93	0.77	0.78	0.81	0.02	0.13	0.01	0.27
20:1n-9	0.81	0.84	0.79	0.87	0.83 <sup>x,y</sup>	0.88 <sup>y</sup>	0.77 <sup>x</sup>	0.02	0.34	0.01	0.01
20:4n-6	0.24	0.25	0.22	0.28	0.23	0.26	0.26	0.01	0.55	0.01	0.15
20:5n-3 <sup>4</sup>	0.01	0.02	—	—	—	—	—	0.002	0.03	0.01	0.01
0%	—	—	0.04 <sup>f</sup>	0.002 <sup>i</sup>	—	—	—	—	—	—	—
CWG	—	—	0.02 <sup>g</sup>	0.003 <sup>i</sup>	—	—	—	—	—	—	—
BT	—	—	0.03 <sup>h</sup>	0.001 <sup>i</sup>	—	—	—	—	—	—	—
Total CLA <sup>4</sup>	1.52	1.64	—	—	—	—	—	0.08	0.07	0.01	0.01
0%	—	—	2.98 <sup>f</sup>	0.24 <sup>h</sup>	—	—	—	—	—	—	—
CWG	—	—	2.53 <sup>g</sup>	0.27 <sup>h</sup>	—	—	—	—	—	—	—
BT	—	—	2.95 <sup>f</sup>	0.51 <sup>i</sup>	—	—	—	—	—	—	—
Total SFA	39.80	39.14	43.07	35.88	41.73 <sup>x</sup>	37.76 <sup>y</sup>	38.93 <sup>y</sup>	0.54	0.29	0.01	0.01
Total MUFA	44.21	44.68	41.40	47.49	42.03 <sup>x</sup>	45.14 <sup>y</sup>	46.17 <sup>y</sup>	0.66	0.54	0.01	0.01
Total PUFA	16.07	17.15	16.65	16.57	16.35	16.81	16.67	0.48	0.06	0.88	0.79
Total UFA <sup>5</sup>	60.28	61.83	58.06	64.05	58.38 <sup>x</sup>	61.95 <sup>y</sup>	62.84 <sup>y</sup>	0.88	0.13	0.01	0.01
Iodine value	65.71	68.02	64.24	69.50	64.33 <sup>x</sup>	67.75 <sup>y</sup>	68.53 <sup>y</sup>	1.1	0.07	0.01	0.02

<sup>f-i</sup>Within the CLA × SBO interaction, simple-effect means with different superscripts differ ( $P < 0.05$ ).

<sup>x,y</sup>Within a row, means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 180 pigs; Rac treatments were imposed at the completion of wk 4 of the experiment.

<sup>2</sup>Diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>3</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

<sup>4</sup>Interaction of CLA and dietary-fat treatments ( $P < 0.05$ ).

<sup>5</sup>UFA = unsaturated fatty acids.

is surprising given that ractopamine has been shown to decrease de novo lipogenesis in porcine adipocytes (Mills et al., 1990). Furthermore, we hypothesize that ractopamine induced reduction in lipogenesis would reduce the palmitic acid content of adipose tissue. These data suggest that feeding ractopamine had little effect on the fatty acid profiles of porcine tissues and that further research is necessary to characterize the effects of ractopamine on the fat metabolism of the pig.

The increased percent lean found in pigs fed ractopamine is likely due to both a reduction in adipose tissue accretion and a corresponding increase in muscle protein synthesis. As previously discussed, ractopamine inhibited lipogenesis in porcine adipose tissue

(Mills et al., 1990). Recently, it has been noted that  $\beta$ -adrenergic receptor agonists, including ractopamine, increased apoptosis in mouse adipose tissue (Page et al., 2004). Increased apoptosis in adipocytes may at least partially explain why pigs fed ractopamine generally have less body fat. However, more research is necessary to determine whether ractopamine induces apoptosis in porcine adipocytes. Furthermore, it has been shown that pigs fed ractopamine have an increase in muscle protein synthesis (Bergen et al., 1989; Adeola et al., 1992). Mechanistically, the increase in muscle protein synthesis may result from the increased myofibrillar gene expression found in pigs fed ractopamine (Grant et al., 1993). Further research is neces-

**Table 13.** Effects of ractopamine (Rac), CLA, and dietary fat type on fatty acid profiles of LM in pigs at wk 8

Fatty acid, %	Rac <sup>1</sup>		CLA <sup>2</sup>		Fat type <sup>3</sup>			SEM	P-value		
	0 ppm	10 ppm	CLA	SBO	0%	CWG	BT		Rac	CLA	Fat
14:0	1.18	1.22	1.42	0.98	1.18	1.19	1.23	0.04	0.40	0.01	0.66
16:0	24.79	25.12	27.07	22.84	25.46	24.94	24.47	0.43	0.51	0.01	0.30
16:1n-7 <sup>4</sup>	2.92	3.07	—	—	—	—	—	0.19	0.35	0.01	0.58
0%	—	—	3.51 <sup>h</sup>	2.63 <sup>i</sup>	—	—	—	—	—	—	—
CWG	—	—	2.93 <sup>i</sup>	2.83 <sup>i</sup>	—	—	—	—	—	—	—
BT	—	—	3.70 <sup>h</sup>	2.37 <sup>i</sup>	—	—	—	—	—	—	—
18:0	15.57	15.18	16.14	14.61	15.91	15.52	14.68	0.40	0.41	0.01	0.10
18:1n-9 <sup>4</sup>	34.37	34.14	—	—	—	—	—	1.2	0.82	0.01	0.97
0%	—	—	34.10 <sup>h</sup>	34.67 <sup>h</sup>	—	—	—	—	—	—	—
CWG	—	—	30.76 <sup>i</sup>	37.44 <sup>j</sup>	—	—	—	—	—	—	—
BT	—	—	34.07 <sup>h</sup>	34.49 <sup>h</sup>	—	—	—	—	—	—	—
18:1n-7 <sup>4</sup>	3.62	3.80	—	—	—	—	—	0.12	0.08	0.01	0.51
0%	—	—	3.57 <sup>h</sup>	3.96 <sup>i</sup>	—	—	—	—	—	—	—
CWG	—	—	3.36 <sup>h</sup>	4.12 <sup>i</sup>	—	—	—	—	—	—	—
BT	—	—	3.77 <sup>h</sup>	3.48 <sup>h</sup>	—	—	—	—	—	—	—
18:2n-6	11.74	11.91	9.94	13.71	10.68	11.92	12.88	1.2	0.91	0.01	0.45
18:2 <i>cis</i> -9 <i>trans</i> -11	0.51	0.56	1.01	0.06	0.56	0.59	0.46	0.09	0.68	0.01	0.57
18:2 <i>trans</i> -10 <i>cis</i> -12	0.10	0.11	0.220	0.002	0.10	0.14	0.09	0.02	0.65	0.01	0.12
18:2 <i>cis</i> -9 <i>cis</i> -11	0.010	0.003	0.011	0.002	0.006	0.011	0.003	0.01	0.26	0.21	0.59
18:2 <i>trans</i> -9 <i>trans</i> -11	ND <sup>5</sup>	ND	ND	ND	ND	ND	ND	—	—	—	—
18:3n-6	0.14	0.04	0.06	0.12	0.16	0.03	0.08	0.04	0.05	0.18	0.13
18:3n-3	0.48	0.64	0.68	0.44	0.68	0.42	0.57	0.16	0.41	0.21	0.55
20:1n-9	0.66	0.67	0.64	0.69	0.66	0.66	0.66	0.02	0.53	0.08	0.99
20:4n-6 <sup>4,6,7</sup>	—	—	—	—	—	—	—	0.35	0.07	0.01	0.40
0%	3.03 <sup>h</sup>	2.95 <sup>h</sup>	2.12 <sup>h</sup>	3.86 <sup>ij</sup>	—	—	—	—	—	—	—
CWG	2.88 <sup>h</sup>	3.03 <sup>h</sup>	2.78 <sup>h,i</sup>	3.13 <sup>h,i</sup>	—	—	—	—	—	—	—
BT	4.47 <sup>i</sup>	2.48 <sup>h</sup>	2.24 <sup>h</sup>	4.70 <sup>j</sup>	—	—	—	—	—	—	—
CLA	2.35 <sup>h</sup>	2.41 <sup>h</sup>	—	—	—	—	—	—	—	—	—
SBO	4.57 <sup>i</sup>	3.23 <sup>h</sup>	—	—	—	—	—	—	—	—	—
20:5n-3	0.07	0.09	0.09	0.06	0.08	0.08	0.07	0.02	0.33	0.16	0.90
Total CLA	0.63	0.68	1.24	0.07	0.67	0.74	0.55	0.11	0.71	0.01	0.45
Total SFA	41.53	41.52	44.63	38.42	42.55	41.65	40.38	0.75	0.99	0.01	0.14
Total MUFA	41.56	41.68	40.56	42.68	41.88	41.39	41.60	1.0	0.92	0.08	0.95
Total PUFA	16.89	16.56	14.54	18.91	15.60	16.54	18.03	1.4	0.84	0.01	0.47
Total UFA <sup>8</sup>	58.45	58.24	55.10	61.59	57.48	57.93	59.63	0.78	0.81	0.01	0.14
Iodine value	61.47	61.61	57.90	65.18	60.15	61.01	63.47	1.5	0.94	0.01	0.30

<sup>h-j</sup>Within the CLA × SBO interaction, simple-effect means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>n = 180 pigs; Rac treatments were imposed at the completion of wk 4 of the experiment.

<sup>2</sup>Diets contained 1% of a 60% CLA product or 1% soybean oil (SBO).

<sup>3</sup>Added fat treatments consisted of 0% added fat, 5% choice white grease (CWG), or 5% beef tallow (BT).

<sup>4</sup>Interaction of CLA and dietary-fat treatments ( $P < 0.05$ ).

<sup>5</sup>ND = not detected.

<sup>6</sup>Interaction of Rac and dietary-fat treatments ( $P < 0.05$ ).

<sup>7</sup>Interaction of CLA and Rac treatments ( $P < 0.05$ ).

<sup>8</sup>UFA = unsaturated fatty acids.

sary to determine the cellular signaling mechanisms that ultimately lead to increased muscle protein synthesis in pigs fed ractopamine.

As found in other studies, feeding CLA (Eggert et al., 2001) or compounds containing CLA (O'Quinn et al., 2000) to growing and finishing pigs increased belly firmness. Likewise, we found that CLA increased the abundance of SFA, decreased the abundance of UFA, and decreased the IOV of pig belly tissue. The increased saturation of the belly tissue fatty acid profile may explain the increase in belly firmness noted in pigs fed CLA. Furthermore, we found that ractopamine tended to decrease belly firmness scores, but this trend was not observed in the hanging belly length measurements measure. Indeed, ractopamine might

have slightly decreased the SFA content of belly tissue, but the effect of ractopamine on belly firmness and fatty acid content was small compared with the effect of CLA.

The results of this experiment indicated that CLA increased the SFA content of porcine tissues and enhanced carcass characteristics such as leanness and belly firmness in pigs fed ractopamine as well as pigs not fed ractopamine. Therefore, feeding CLA may be a nutritional means to maintain carcass quality and firmness when other management practices that alter carcass quality are used. Ractopamine had relatively little effect on the fatty acid composition of carcass tissues. The data presented herein also indicate that CWG and BT are essentially equivalent in terms of

their effects on growth performance and carcass fatty acid composition.

## LITERATURE CITED

- Adeola, O., R. O. Ball, and L. G. Young. 1992. Porcine skeletal muscle myofibrillar protein synthesis is stimulated by ractopamine. *J. Nutr.* 122:488–495.
- AOAC. 1990. Official Methods of Analysis. 15th ed. Assoc. Offic. Anal. Chem., Arlington, VA.
- Bee, G. 2000. Dietary conjugated linoleic acids alter adipose tissue and milk lipids of pregnant and lactating sows. *J. Nutr.* 130:2292–2298.
- Bergen, W. G., S. E. Johnson, D. M. Skjaelund, A. S. Babiker, N. K. Ames, R. A. Merkel, and D. B. Anderson. 1989. Muscle protein metabolism in finishing pigs fed ractopamine. *J. Anim. Sci.* 67:2255–2262.
- Bligh, E. G., and W. J. Dyer. 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem.* 37:911–917.
- Dugan, M. E. R., J. L. Aalhus, A. L. Schaefer, and J. K. G. Kramer. 1997. The effect of conjugated linoleic acid on fat to lean repartitioning and feed conversion in pigs. *Can. J. Anim. Sci.* 77:723–725.
- Eggert, J. M., M. A. Belury, A. Kempa-Steczko, S. E. Mills, and A. P. Schinckel. 2001. Effects of conjugated linoleic acid on the belly firmness and fatty acid composition of genetically lean pigs. *J. Anim. Sci.* 79:2866–2872.
- Ellis, N. R., and H. S. Isbell. 1926. Soft pork studies 2. The influence of the character of the ration upon the composition of the body fat of hogs. *J. Biol. Chem.* 69:219–238.
- Grant, A. L., D. M. Skjaerlund, W. G. Helferich, W. G. Bergen, and R. A. Merkel. 1993. Skeletal muscle growth and expression of skeletal muscle  $\alpha$ -actin mRNA and insulin-like growth factor I mRNA in pigs during feeding and withdrawal of ractopamine. *J. Anim. Sci.* 71:3319–3326.
- Hargrave, K. M., C. Li, B. J. Meyer, S. D. Kachman, D. L. Hartzell, M. A. Della-Fera, J. L. Miner, and C. A. Baile. 2002. Adipose depletion and apoptosis induced by trans-10, cis-12 conjugated linoleic acid in mice. *Obes. Res.* 10:1284–1290.
- Joo, S. T., J. I. Lee, Y. L. Ha, and G. B. Park. 2002. Effects of dietary conjugated linoleic acid on fatty acid composition, lipid oxidation, color, and water-holding capacity of pork loin. *J. Anim. Sci.* 80:108–112.
- Mersmann, H. J. 1998. Overview of the effects of  $\beta$ -adrenergic receptor agonists on animal growth including mechanism of action. *J. Anim. Sci.* 76:160–172.
- Mildner, A. M., and S. D. Clarke. 1991. Porcine fatty acid synthase: cloning of a complementary DNA, tissue distribution of its mRNA and suppression of expression by somatotropin and dietary protein. *J. Nutr.* 121:900–907.
- Mills, S. E., C. Y. Liu, and A. P. Schinckel. 1990. Effects of ractopamine on adipose tissue metabolism and insulin binding in finishing hogs. Interaction with genotype and slaughter weight. *Domest. Anim. Endocrinol.* 7:251–264.
- Miner, J. L., C. A. Cederberg, M. K. Nielsen, X. Chen, and C. A. Baile. 2001. Conjugated linoleic acid (CLA), body fat, and apoptosis. *Obes. Res.* 9:129–134.
- NPPC. 1991. Procedures to Evaluate Market Hogs. 3rd ed. Natl. Pork Prod. Council, Des Moines, IA.
- NPPC. 1999. Pork Quality Standards. Natl. Pork Prod. Council, Des Moines, IA.
- NRC. 1998. Nutrient Requirements of Swine. 9th ed. Natl. Acad. Press, Washington, DC.
- O'Quinn, P. R., J. L. Nelssen, R. D. Goodband, J. A. Unruh, J. C. Woodworth, J. S. Smith, and M. D. Tokach. 2000. Effects of modified tall oil versus a commercial source of conjugated linoleic acid and increasing levels of modified tall oil on growth performance and carcass characteristics of growing-finishing pigs. *J. Anim. Sci.* 78:2359–2368.
- Ostrowska, E., M. Muralitharan, R. F. Cross, D. E. Bauman, and F. R. Dunshea. 1999. Dietary conjugated linoleic acids increase lean tissue and decrease fat deposition in growing pigs. *J. Nutr.* 129:2037–2042.
- Page, K. A., D. L. Hartzell, C. Li, A. L. Westby, M. A. Della-Fera, M. J. Azain, T. D. Pringle, and C. A. Baile. 2004.  $\beta$ -adrenergic receptor agonists increase apoptosis of adipose tissue in mice. *Domest. Anim. Endocrinol.* 26:23–31.
- Ramsay, T. G., C. M. Evock-Clover, N. C. Steele, and M. J. Azain. 2001. Dietary conjugated linoleic acid alters fatty acid composition of pig skeletal muscle and fat. *J. Anim. Sci.* 79:2151–2161.
- Rasmussen, A., and J. R. Stouffer. 1996. New method for determination of drip loss in pork muscles. Paper presented at the 34th Int. Congr. Meat Sci. Technol., Brisbane, Australia.
- Satory, D. L., and S. B. Smith. 1999. Conjugated linoleic acid inhibits proliferation but stimulates lipid filling of murine 3T3-L1 preadipocytes. *J. Nutr.* 129:92–97.
- Seerley, R. W., J. P. Briscoe, and H. C. McCampbell. 1978. A comparison of poultry and animal fat on performance, body composition and tissue lipids of swine. *J. Anim. Sci.* 46:1018–1023.
- Shantha, N. C., E. A. Decker, and B. Henng. 1993. Comparison of methylation methods for the quantification of conjugated linoleic acid isomers. *J. AOAC Int.* 76:644–649.
- Smith, S. B., T. S. Hively, G. M. Cortese, J. J. Han, K. Y. Chung, P. Catenada, C. D. Gilbert, V. L. Adams, and H. J. Mersmann. 2002. Conjugated linoleic acid depresses the  $\delta^9$  desaturase index and stearoyl coenzyme A desaturase enzyme activity in porcine subcutaneous adipose tissue. *J. Anim. Sci.* 80:2110–2115.
- Smith, S. B., H. J. Mersmann, E. O. Smith, and K. G. Britain. 1999. Stearoyl-coenzyme A desaturase gene expression during growth in adipose tissue from obese and crossbred pigs. *J. Anim. Sci.* 77:1710–1716.
- Stahly, T. S., and G. L. Cromwell. 1979. Effect of environmental temperature and dietary fat supplementation on the performance and carcass characteristics of growing and finishing swine. *J. Anim. Sci.* 49:1478–1488.
- Stoller, G. M., H. N. Zerby, S. J. Moeller, T. J. Baas, C. Johnson, and L. E. Watkins. 2003. The effect of feeding ractopamine (Paylean) on muscle quality and sensory characteristics in three diverse genetic lines of swine. *J. Anim. Sci.* 81:1508–1516.
- Swan, J. E., F. C. Parrish, B. R. Weigand, S. T. Larsen, T. J. Baas, and E. P. Berg. 2001. Total body electrical conductivity (TO-BEC) measurement of compositional differences in hams, loins, and bellies from conjugated linoleic acid (CLA)-fed stress-genotype pigs. *J. Anim. Sci.* 79:1475–1482.
- Warnants, N., M. J. Van Oeckel, and C. V. Boucque. 1999. Incorporation of dietary polyunsaturated fatty acids into pork fatty tissues. *J. Anim. Sci.* 77:2478–2490.
- Williams, N. H., T. R. Cline, A. P. Schinckel, and D. J. Jones. 1994. The impact of ractopamine, energy intake, and dietary fat on finisher pig growth performance and carcass merit. *J. Anim. Sci.* 72:3152–3162.